PENGHASILAN DAN PENCIRIAN BAHAN BUMBUNG DARIPADA GENTIAN ASLI

ABSTRAK

Gentian asli diekstrakkan daripada tumbuh-tumbuhan dan mereka secara meluas digunakan sebagai tetulang komposit dalam menghasilkan bahan-bahan bumbung. Walaubagaimanapun, gentian asli menghadapi beberapa masalah seperti keboleh basahan, ketidak serasian dengan beberapa matriks polimer dan penyerapan kelembapan yang tinggi. Bahan bumbung moden juga mahal dan tidakter biodegradasi. Kos pengeluaran yang rendahdanbahan-bahan bumbung terbiodegradasikan boleh dihasilkan dengan menggunakan gentian semulajadi komposit bertetulang (NFRC). Kesandamar pengawetan ejen peratusan (RCA) dan serat jumlah lapisan NFRC pada sifat haba dan mekanikal telah dikaji. Gentian kenaf telah disediakan dalam polyester tikar berbentuk dan tak tepu telah disembuhkan dengan 10, 15 dan 20% daripada RCA (2-butanone peroxide). Kenaf-komposit poliester (KPC) telah disintesis dengan menggunakan 1 dan 2 lapisan gentian kenaf yang dicampur dengan polyester sembuh dengan menggunakan kaedah tangan meletakkan-atas. Selepasitu, specimen ujian untuk ujian tegangan, ujian hentaman Charpy dan ujian penyerapan air telah disediakan. Ujian mekanikal telah dijalankan untuk menilaisifat-sifat KPC. Tegangan dan kekuatan impak KPC telah meningkat dengan peratusan RCA dan lapisan gentian kenaf kerana kenaikan pemautkacukan antara rantaian polimer dan darjah halangan. Walaubagaimanapun, kenaikan lapisan serat meningkatkan penyerapan air komposit kerana sifat hydrophilic gentian kenaf. Ujian terma seperti analisis Termogravimetri (TGA) dan calorimeter pengimbasan kebezaan (DSC) analisis telah dijalankan untuk menilai kestabilan termakomposit. Kenaikan peratusan RCA dan lapisan gentian menurunkan suhu degradasi komposit yang menurunkan kestabilan termal komposit. Walaubagaimanapun, kenaikan peratusan RCA dan lapisan serat meningkatkan takat lebur komposit. Ia boleh membuat kesimpulan bahawa bahan-bahan bumbung yang sesuai akan dihasilkan oleh KPC selepas pengoptimuman jumlah lapisan gentian dan RCA kesan peratusan.

PRODUCTION AND CHARACTERISATION OF ROOFING MATERIALS FROM NATURAL FIBRES

ABSTRACT

Natural fibres are extracted from plants and they are widely being used as the reinforcement of composites in producing roofing materials. However, natural fibres are facing several problems such as poor wettability, incompatibility with some polymeric matrices and high moisture absorption. Modern roofing materials are also expensive and non-biodegradable. Low production cost and biodegradable roofing materials can be produced by using natural fibres reinforced composites (NFRC). The effects of resin curing agent (RCA) percentage and fibre layer amount of NFRC on thermal and mechanical properties were studied. The kenaf fibre was prepared in mat shaped and unsaturated polyester was cured with 10, 15 and 20% of RCA (2-Butanone peroxide). Kenaf-polyester composite (KPC) was synthesised by using 1 and 2 layers of kenaf fibre layer which mixed with cured polyester by using hand lay-up method. After that, test specimens for tensile test, Charpy impact test and water absorption test were prepared. Mechanical tests were carried out to evaluate the properties of KPC. The KPC tensile and impact strengths were increased with the RCA percentage and kenaf fibre layer due to the increment of cross linker between polymer chains and degree of obstruction. However, the increment of fibre layer increased the water absorption of composites due to the hydrophilic properties of kenaf fibre. Thermal tests like thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) analysis were carried out to evaluate the thermal stability of composites. Increment of RCA percentages and fibre layers decreased the degradation temperatures of composites which decreased the thermal stability of composites. Nevertheless, increment of RCA percentage and fibre layers increased the melting points of composites. It could be concluded that roofing materials are suitable to be produced by KPC after the optimisation of fibre layer amount and RCA percentage effect.

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NF	Natural Fibre
NFRC	Natural Fibre Reinforced Composite
RCA	Resin Curing Agent
KF	Kenaf Fibre
KPC	Kenaf-Polyester Composite
TGA	Thermogravimetric Analysis
DSC	Differential Scanning Calorimetry
T_d	Degradation Temperature
T_{max}	Temperature of Maximum Degradation
TM	Tensile Modulus
TS	Tensile Strength

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Natural fibre (NF), often referred to as vegetable fibres, are extracted from plants. They are categorised by depending on the part of the plant they are extracted from. NFs are readily available in large quantities in many countries and they represent a continuous renewable source. There are various types of NF such as sisal, kenaf, flax, jute, oil palm empty fruit bunch, coir and so on. The characteristics for those different fibres are slightly different but all of them can be chemically or mechanically processed to enhance their properties.

Nowadays, the use of NF for the reinforcement of the composites has received increasing attention. This is because NF has many significant advantages over synthetic fibres. NF can be considered as naturally occurring composites consisting mainly of cellulose fibrils (fibres) embedded in lignin matrix (resin). These cellulose fibrils are aligned along the length of the fibre, irrespective of its origin. This type of alignment provides maximum tensile and flexural strengths. Besides, these fibres are high electrical resistance and also being thermally and acoustically insulating (Satyanarayana et al., 1990). Recently, many types of natural fibres have been investigated including flax, hemp, jute straw, wood, rice husk, wheat, grass, oil palm empty fruit bunch, kenaf, sisal, coir, banana fibre and pineapple leaf fibre.

Kenaf fibres provide high stiffness and strength values. They also have higher aspect ratios making them suitable to be used as reinforcement in polymer composites (Sanadi et al. 1995). Kenaf is an herbaceous annual plant, a warm-season annual row crop and can be obtained easily in Malaysia which main plantation distributed in Kelantan and Pahang. The attractive features of kenaf fibres are the low cost, lightweight, renewability, biodegradability and high specific mechanical properties. Kenaf has a bast fibre which contains 75% cellulose and 15% lignin and offers the advantages of being biodegradable and environmentally safe (Mansur & Aziz, 1983).

Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder maintains the position and orientation of the reinforcement (Taj, Munawar and Khan, 2007). Natural fibres reinforced composites (NFRC) are hybrid materials made of a polymer resin which reinforced by natural fibres. It combines the high mechanical and physical performance of the fibres and the appearance, bonding and physical properties of polymers (Rijswijk, Brouwer and Beukers, 2001). The use of

NF in polymeric matrices such as polyester, polyethylene, polypropylene and epoxy resins has been explored widely. For example, jute-epoxy composites, coir-polyester composites and sisal-polyethylene composites have been commonly applied on industry.

Recently, there is increasing demand in low cost housing. On the other hand, there us the lack of suitable low cost roofing. According to Cook et al. (1978), the roof is an essential component of housing which is critical to shelter, thermal comfort and privacy. In many developing countries, roofing alone represents more than 50% of the total construction cost of a low cost house. The application of NFRC have been explored widely especially in producing roofing material due to its characteristics. Therefore, further research on low cost and biodegradable roofing material should be continued by using NFRC.

1.2 Problem Statement

There is an increasing demand for low cost roofing materials especially in developing countries due to the growth of low cost housing. On the other hand, modern roofing materials such as corrugated iron and aluminium are very expensive and non-environmentally friendly. As mentioned above, roofing is an important component for a dwelling. Therefore, NFRC by using biodegradable polymer as matrices which are cheap, environmentally friendly, biodegradable and renewable are alternative materials in producing roofing panels.

However, NFRC are facing several problems such as poor wettability, incompatibility with some polymeric matrices and high moisture absorption. Composite materials which made from unmodified natural fibres will exhibit unsatisfactory mechanical properties. Therefore, surface treatment on natural fibre can be used prior to composite fabrication. The properties can also be improved by physical treatments and chemical treatments.

1.3 Research Objectives

The objectives of this study are:

(i) To produce low cost and biodegradable roofing materials from NFRC.

(ii) To study the effect of resin curing agent (RCA) percentage on the thermal and mechanical properties of NFRC.

(iii) To investigate the effect of kenaf fibre layer amount on the thermal and mechanical properties of NFRC.

1.4 Scope of Study

This research was carried out on the preparation and characterisation of kenaf fibre reinforced polyester composites. The scopes of study are as follow:

(i) Preparation of composites with various resin curing agent percentage (10, 15 and 20%).

(ii) Preparation of composites with various amount of kenaf fibre layers (1 and 2 layers).

(iii) Characterisations of composites with various mechanical (tensile test, charpy impact test and water absorption test) and thermal (thermogravimetric analysis and differential scanning calorimetry analysis) tests.

1.5 Significance of Study

This study is able to produce biodegradable roofing material which is more environmentally friendly compared to modern roofing materials such as corrugated iron and aluminium. Besides, the low production cost will also be suitable for rural and developing country in producing roofing materials.

This study is also able to determine the effect of resin curing agent percentage and fibre layers on composites and thus, the optimum mechanical and thermal properties of kenaf fibre reinforced composites can be obtained. Therefore, it is useful not only in producing roofing materials, but also useful in other manufacturing sectors which involve NFRC as the raw materials.

CHAPTER 2

LITERATURE REVIEW

2.1 Natural Fibres

Farmers around the world produce many types of natural fibres, planting crops and rearing animals. Natural fibre is a collection of cells having long length and negligible diameter. They can be obtained as continuous filaments or discrete elongated pieces similar to thread. They can be spun or twisted into yarn such as cloth and also can be converted into nonwoven fabircs, such as paper and felt (Islam et al., 2012). Furthermore, natural fibres can be considered as naturally occurring composites consisting mainly of cellulose fibrils (fibres) embedded in lignin matrix (Satyanarayana, Sukumaran, Mukherjee, Pavithran & Pillai, 1990). Natural fibres may be from the plant's fruit (eg. cotton or coir), stems (eg. flax, jute, kenaf and hemp) or leaf (eg. sisal). They are lignocelluloses based natural plant fibres which widely be used as reinforcements in the polymer composites.

Natural fibres are natural resources which are renewable and environmentally friendly. There is a growing interest in the development of natural fibres in industry because of their advantages. According to Satyanarayana et. al. (1990), natural fibres have the following advantages: (i) they can lead to high specific strength properties although they have poor strength properties due to low density. In addition, they are high resistance to crack propagation, (ii) they are having low cost and low energy consumption compared with synthetic fibres, (iii) they are non-toxic, (iv) Most of the scientific data on the structure and properties of natural fibres are well known, so that suitable applications for them can be found. In addition, compared to synthetic fibre, natural fibre has many advantages such as recoverability, biodegradation, flammability, non-toxicity, and other excellent properties (Qin et al., 2011).

Furthermore, a lot of work has been done to take advantage of the wide range in the properties of natural fibres. Arrakhiz et al., (2012) have reported that to achieve better mechanical and thermal properties, varying the fibre content, the chemical treatment used and the choice of the polymer matrix were studied. For instance, it is found that some mechanical properties as Young's modulus increased incredibly with increasing fibre loading. It was also mentioned some examples of a variability of chemical treatments used in the literature, to improve mechanical properties of composites. Moreover, the right choice of polymer matrix also had an impact on the stress rupture of the composites (Satyanarayana et al., 1990).

2.1.1 Kenaf Fibres

Kenaf fibre is obtained from stems of plants genus Hibiscus, family of Malvaceae and the species of H. Cannibinus. It requires less water to grow because it has growing cycle of 150 to 180 days with average yield of 1700kg/ha (Thiruchitrambalam, Alavudeen, Athijayamani, Venkateshwaran, & Elaya Perumal, 2009). Traditionally, kenaf bast fibres are used and known for rope, twine, and course sacking materials. Kenaf natural fibres are biodegradable and environmentally friendly crop and have been found to be important source fibres for composites and other industrial applications. Kenaf fibres also have a potential as reinforced fibre in thermosets and thermoplastics composites (Yuhazri et.al, 2011).

According to Thiruchitrambalam et. al. (2009), kenaf fibres have many advantages as reinforcement in fibre reinforced polymer composites which are low density, low cost, non-abrasiveness during processing, high specific mechanical properties, biodegradability, good thermal properties, sustainable and renewable sources. Therefore, kenaf fibre is chosen as the reinforcing fibre for natural fibre reinforced composites.

Figure 2.1: Kenaf Fibre
(**Source**: Cheng, Kuwn, Phongsakorn, Dan & Saifudin, 2009)

2.2 Composites

Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement (Taj et. al., 2007)

According to Rijswijk et. al. (2001), composites are hybrid materials made of a polymer resin reinforced by fibres, combining the high mechanical and physical performance of the fibres and the appearance, bonding and physical properties of polymers. Therefore, the combination of natural fibre and polymer resin can improve the physical and mechanical properties which are suitable for various applications.

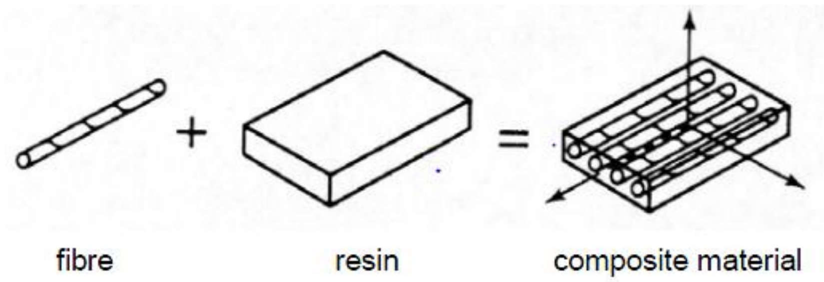

Figure 2.2: Composites Composition
(**Source**: Rijswijk et.al, 2001)

By this joining, the poor capabilities and drawbacks of the individual components disappear. For instance, composites combine a high stiffness and strength with a low weight and their corrosion resistance is often excellent. Composites have worked their way up amongst wood and metal due to their outstanding price performance ratio during a lifetime. A powerful approach in improving this ratio is to minimise the steps required from raw material to end product (Rijswijk et. al., 2001).

2.3 Natural Fibre Reinforced Composites

The combination of natural fibres as the reinforcement with the polymer resins contribute to natural fibre reinforced composites. According to Satyanarayana et. al. (1990), it is expected that when natural fibres are incorporated in low-modulus matrix such as polyester to become natural fibre reinforced composites, they would yield materials with better physical and mechanical properties which suitable for various applications.

In addition, natural fibre reinforced composites, by using biodegradable polymers as matrices, are the most environmental friendly materials, which can be composed at the end of their life cycle (Taj et. al., 2007). There are various types of natural fibre reinforced composites such as kenaf-polyester composites, sisal-polyethylene composites, coir-polyester composites, jute-epoxy composites and others. Each of them represents different type of physical and mechanical properties.

2.3.1 Kenaf-Polyester Composites

The combination of kenaf fibre as the reinforcement with the polyester as the polymer resins contribute to kenaf-polyester composites. There are many advantages of kenaf-polyester composites compared to other natural fibre reinforced composites. According to Thiruchitrambalam et al. (2009), the kenaf–polyester composites manufactured have a higher specific modulus than sisal, coir, and even E-glass thereby providing an opportunity for replacing existing materials with a higher strength, lower cost and more environmentally friendly materials. Therefore, kenaf-polyester fibre is chosen to be used in the production of roofing materials.

2.4 Methods of Improving Composites Properties

Natural fibres are hydrophilic in nature as they are derived from lignocellulose, which contain strongly polarized hydroxyl groups. Therefore, they are incompatible with hydrophobic thermoplastics such as polyester. According to John and Anandjiwala (2008), the major limitations of using natural fibres as reinforcements in polymer matrices include poor interfacial adhesion between polar-hydrophilic fibre and non-polar hydrophobic matrix, and difficulties in mixing due to poor wetting of the fibre with the matrix. This would lead to composites with weak interface.

According to Taj et. al. (2007) on the limitation of natural fibre reinforced composites; they are poor wettability, incompatibility with some polymeric matrices and high moisture absorption. Composite materials made with the use of unmodified plant fibres frequently exhibit unsatisfactory mechanical properties. Furthermore, lack of good interfacial adhesion and poor resistance to moisture absorption made the use of natural fibre reinforced composites less attractive (Joseph & Thomas, 1995).

Therefore, notable disadvantages of natural fibres are their polarity which makes it incompatible with hydrophobic matrix and their poor resistance to moisture absorption. However, these problems can be overcome by treating these fibres with suitable methods such as alkali treatment and surface modification through coupling agents.

2.4.1 Surface Modification through Silane Coupling Agent

These chemicals are hydrophilic compounds with different groups appended to silicon such that one end will interact with matrix and the other end can react with hydrophilic fibre, which act as a bridge between them (John & Anandjiwala, 2008).

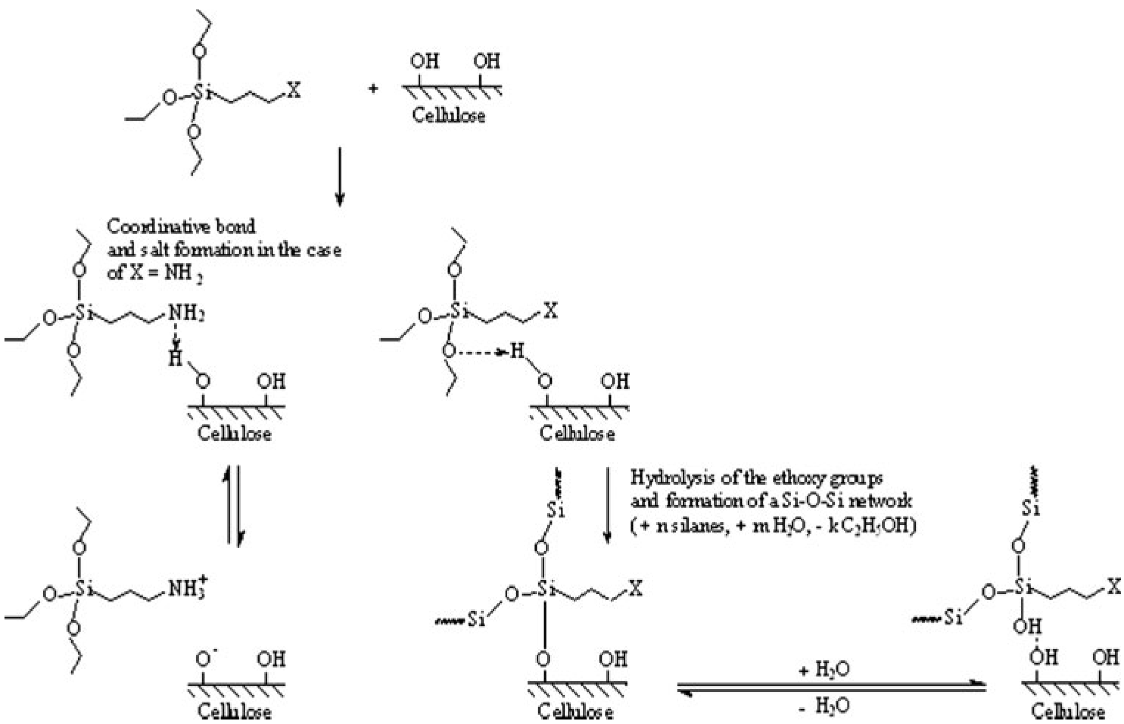

Figure 2.3: Interaction of Silanes with Cellulosic Fibres
(**Source**: John & Anandjiwala, 2008)

According to Taj et. al. (2007), silane chemical coupling presents three main advantages: (i) they are commercially available in large scale, (ii) at one end, they bear alkoxysilane groups capable of reacting with fibres OH-rich surface, and (iii) at the second end, they have a large number of functional groups which can be tailored as a function of the matrix to be used. Therefore, there will be a good compatibility between the natural fibre and the polymer matrix or even covalent bonds between them. However, the cost for this surface treatment is high.

2.4.2 Alkaline Treatment

Alkaline treatment leads to the increase in the amount of amorphous cellulose at the expense of crystalline cellulose. The important modification occurring here is the removal of hydrogen bonding in the network structure. In this structure, the OH-groups of the cellulose are converted into ONa-groups, expanding the dimensions of molecules. Subsequent rinsing with water will remove the linked Na-ions and convert the cellulose to a new crystalline structure (John & Anandjiwala, 2008).

Besides that, according to Taj et. al. (2007), the effect of chemical treatment of natural fibres with sodium hydroxide has been reported for coir, kenaf and sisal fibres. This modification results in an increase in adhesive bonding and thus improves ultimate tensile strength up to 30%. Joseph et. al. (1996) have also investigated the influence of chemical treatment with sodium hydroxide on the properties of kenaf-polyester composites. The observed enhancement in properties of the composites and attributed this to the strong bonding between kenaf and polyester matrix. Therefore, due to the advantages and the lower cost of alkaline treatment, it is chosen for the chemical treatment for kenaf fibre.

2.5 Production Methods

In order to produce roofing material from kenaf-polyester composites, there are many methods can be used such as hand lay-up method, extrusion moulding, injection moulding and compression moulding.

2.5.1 Hand Lay-up Method

The fibres which usually in mats shaped are cut and placed in a mould as shown in Figure 2.4. The resin is applied by rollers. One option is to cure while using a vacuum bag, then it's called vacuum bagging. By applying vacuum, excess air is removed and the atmospheric pressure exerts pressure to compact the composite. The advantages are the high flexibility and the simplicity of the process and the cheap tooling (Rijswijk et.al, 2001).

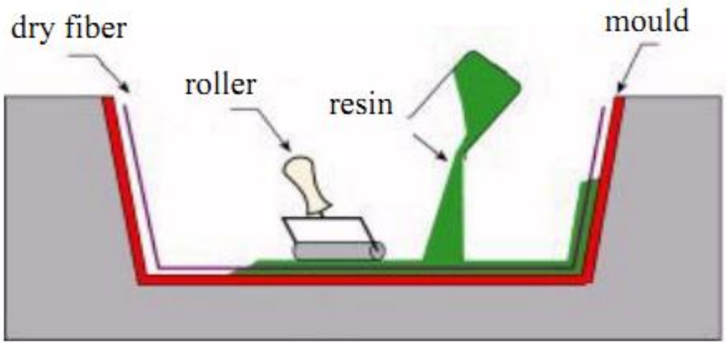

Figure 2.4: Hand Lay-up Method
(**Source**: Rijswijk et.al, 2001)

2.5.2 Extrusion Moulding

Extrusion moulding is a process of producing a continuous work piece by forcing molten plastic through a shaped die. As the hot material exits the die, the material is carried along a conveyor, cooled and after that cut to the desired length. In extrusion moulding, thermoplastic materials are fed from a hopper into the heated barrel of an extruder. A rotating helical screw inside the barrel pushes the plastic through the barrel toward the die located at the end of the machine (Santos et. al., 2007).

Extrusion moulding of plastics is used to make any long shape that has a constant cross section. Pipes, gutters, window sections and decorative trims can all be made using the process. Thermoplastics such as PVC (polyvinylchloride), LDPE (low-density polyethylene, or polythene), HDPE (high density polyethylene) and PP (polypropylene) can all be extruded. Thermoplastics are pliable when they are heated but form a rigid shape once cooled.

However, according to Takashima et. al. (2003) on the disadvantages of extrusion moulding, when the hot plastic exits the extruder, it frequently expands. The expansion of the plastic at this stage of the process is called die swell. Predicting the exact degree of expansion remains problematic as it arises from different factors in the process. Due to unpredictable expansion, we must often accept significant levels of deviation from the product dimensions or tolerance.